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THE TESTING OF A HAZARD POTENTIAL RATING FORM TO EVALUATE THE DEGREE OF HAZARD IN INDUSTRIAL OPERATIONS

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THE TESTING OF A HAZARD POTENTIAL RATING FORM TO

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SUMMARY

Many accident-control procedures presently available to the safety engineer for use in controlling accidents are primarily concerned with past accident performance or with the observation and evaluation of worker behavior, rather than with the hazards inherent in industrial operations. The few procedures that are concerned with the hazards of an operation are primarily of a subjective nature. There is presently no procedure that provides an objective, quantitative method of evaluating the degree of hazard in an industrial operation. A procedure of this type would allow management to direct the safety effort toward those operations with the greatest degree of inherent hazard in an attempt to reduce accidents by concentrating on those operations that have the greatest potential for causing an accident.

A form similar to a job evaluation point rating form has been developed to be used in rating the hazard potential of an industrial operation. In this study, the ability of the use of this form to predict those operations that cause the greatest number of accidents and the most severe accidents was tested. Several operations at two industrial plants were observed and were rated using the previously developed form. The ratings determined were correlated with historical accident data for the operations rated to determine the predictive ability of the form.

The analysis indicated that the hazard ratings were positively correlated with several of the past accident data that were studied. This would indicate that the use of the hazard rating form could provide

an effective procedure to evaluate the degree of hazard in an industrial operation.

CHAPTER I

INTRODUCTION

During the early years of American industry, accidents were thought to be inherent in industrial operations. Management and the employee accepted the belief that accidents were inevitable in the performance of industrial operations and little attempt was made to control these accidents. The attitude was that accidents were a risk incurred in the performance of industrial operations and this should be accepted without question. As time passed, management began to introduce some accident-control measures. These measures were introduced primarily to comply with legislation that had been passed and consisted primarily of the guarding of machinery. These early accident-control measures were regarded as welfare activities and no thought was given to the fact that the reduction of accidents might lead to a more efficient operation and thus an increase in production. However, in 1928, it was shown that an increase in the safety effort could result in an increase in the production effort as the Committee on Safety and Production of the American Engineering Council stated "that there is a positive correlation between safety and efficiency of production and, in general, the safe factory is the efficient factory" (1). This changed management's attitude toward safety and management began to place more emphasis on safety performance in an attempt to realize gains in production.

As industry realized that safety performance plays an important part in the efficient operation of an industrial plant, accident-control activities received increasing emphasis. This led to the development of several accident-control procedures that are used to evaluate safety performance and to indicate the most hazardous operations, plants, and industries. The majority of these procedures are limited to their use by the fact that they are after-the-fact techniques or are concerned primarily with behavior rather than hazards that are inherent in the operations. They are measures of the accidents or behavior that have already occurred and are beneficial only to show the relative safety performance of one operation, plant, or industry as compared to another operation, plant, or industry. Little attempt has been made to evaluate the inherent hazards in industrial operations and thus reduce accidents by controlling the hazards within the operation.

At present the two primary accident-control measures are the frequency rate and the severity rate. They are defined by the United States of America Standards Institute in the following way (2):

$$\text{Disabling Injury Frequency Rate} = \frac{\text{Number of Disabling Injuries} \times 1{,}000{,}000}{\text{Employee-hours of Exposure}}$$

$$\text{Disabling Injury Severity Rate} = \frac{\text{Total Days Charged} \times 1{,}000{,}000}{\text{Employee-hours of Exposure}}$$

The operations, plants, and industries with the highest rates are considered to be the most hazardous and the safety effort is directed toward these. As can be seen these two accident-control indicators are concerned only with disabling injuries and the time which is lost due to these injuries. For adequate statistical reliability sizable manhour exposure is required. In many cases the number of accidents and the amount of exposure within a reasonable time period is relatively small and the rates tend to be unreliable. These rates are computed after the accidents have occurred. If the potential for an accident exists it will not be recognized unless a disabling injury accident has occurred.

Another accident-control measurement is suggested by Thomas H. Rockwell (3). Rockwell suggests using activity sampling methods to determine the extent of unsafe behavior. The procedure consists of taking random instantaneous observations of industrial operations and noting whether the worker is engaged in safe or unsafe behavior. By plotting these data on control charts, it can be determined which operations present the greatest accident potential according to worker behavior. This procedure requires the ability to dichotomize behavior as safe or unsafe. Also no attempt is made to evaluate the seriousness of the unsafe acts committed. The procedure is concerned only with worker behavior and not with hazards inherent in the operations.

Earl J. Ferguson and James M. Daschbach (4) have described an accident-control procedure known as the SAF-HANS method (Safety through Frequency of Hazards Analysis). This procedure makes use of a memo motion camera system to record data on film. The camera is mounted on a fork-lift truck and operated continuously through an entire work shift while the operator of the truck goes about his regular duties. The film is evaluated by noting the number of hazards recorded by the camera. A complete list of the hazards and their frequency is compiled through any desired time period. The safety program then emphasizes the hazards occurring most frequently and the procedure is repeated to evaluate the effectiveness of the program in reducing the indicated hazards. This procedure is limited in that only the hazards seen by the camera will be considered and the hazards noted are those caused by worker behavior and not hazards inherent in the industrial operations.

The use of Safe-t-Scores is an accident-control procedure developed by J. A. Martin (5). This procedure is based on the assumption that the past performance of any group is its best standard for comparison. A base period, or the standard for comparison, is chosen. The Safe-t-Score is then computed. The Safe-t-Score is based on the "t" test which can be used to test the means of two groups of comparable data for significant differences. The Safe-t-Score is defined as follows:

$$\text{Safe-t-Score} = \frac{(\text{Freq. Rate for Current Period}) - (\text{Freq. Rate for Base Period})}{\sqrt{\dfrac{\text{Freq. Rate for Base Period}}{\text{Million Manhours in Current Period}}}}$$

Once the Safe-t-Score has been computed it is compared to a predetermined range to see if the frequency rate under consideration was the same; was significantly worse; or was significantly better than the base year selected. This will allow the safety effort to be directed toward those groups that have significant variations away from their established base. This is an indication that there is an assignable cause for the relatively poor performance of the group and the safety effort will be directed toward the group in an attempt to determine the cause. This procedure is based on accidents that have already occurred and no attempt is made to determine the hazards that caused the accidents and reduce or eliminate them.

Another accident-control procedure is based on the assumption that there is a definite relationship between the rate of safety activities and the injury frequency rate (6). This procedure is known as the activity rate and is defined as follows:

$$\text{activity rate} = \frac{\text{safety activity} \times 5{,}000{,}000}{\text{man-hours worked} \times \text{avg. number of employees}}$$

Safety activity is the sum (during the unit period) of: (1) safety recommendations; (2) unsafe practices reported; (3) unsafe conditions reported; (4) the number of safety meetings held. This procedure provides a quantitative measure of safety activity and enables it to be compared with accident frequency. Thereby, unfavorable trends in accident frequency can be forecast and avoided. The use of the activity rate is limited to unsafe practices and conditions that have already occurred and to the number of safety recommendations and the number of safety meetings held regardless of quality or suitability. The procedure does not indicate the most hazardous operations.

William E. Tarrants (7) discusses the use of the critical incident technique to identify the causal factors (hazards) involved in injurious accidents. In using this technique a number of persons who have performed particular jobs are interviewed. They are asked to recall and describe unsafe acts and unsafe conditions that they can remember existing within these industrial operations. These incidents are transcribed and classified into hazard categories from which accident problem areas can be defined. Unfortunately the use of the critical incident technique is not fully understood by the majority of safety investigators and does not provide a means of quantitatively determining the degree of hazard in industrial operations.

An accident-control procedure which singles out incidents with high accident potential before serious injuries occur is the use of "High Potential Accident Analysis" as proposed by William W. Allison (8). This procedure advocates concentrating on and correcting the hazards that cause high potential accidents that result in minor injuries, property damage, or in no injury at all. High potential accidents are defined as those that did, or under similar or slightly different circumstances, could result in serious injury or damage. This procedure concentrates on the hazards in industrial operations but it is an after-the-fact technique that requires the occurrence of a near injury or an injury accident before becoming concerned with the existing hazard.

There have been several accident-control procedures developed that attempt to evaluate a potentially hazardous activity before it develops. A. D. Swain (9) has proposed evaluating the operation in the design stage. Safety should be integrated into the operation in the initial stages of development. Periodic follow-up inspections would then be made to determine if any hazardous conditions had developed since the operation was implemented. However, this procedure does not provide an objective rating to evaluate the degree of hazard that is present.

Another accident-control procedure that is primarily concerned with hazards that are inherent in industrial operations is that of methods safety analysis as presented by John V. Grimaldi (10). In this procedure each job or operation is first broken down into its elementary steps. These elementary steps are then analyzed, much as an operations analyst investigates the steps of a job with the aim of eliminating those steps that are unnecessary or substituting for those that are inefficient.

However, when conducting a safety analysis the safety investigator is concerned with each step for its possibility for causing an accident. The safety investigator then attempts to eliminate or modify the potentially hazardous steps. This procedure, primarily a methods improvement procedure, provides a somewhat objective means of determining the hazard potential in an industrial operation but it is limited by the fact that it requires a thorough, time-consuming analysis of each operation and it does not allow an objective comparison to be made among different operations.

None of the procedures described provides an objective, quantitative method of evaluating the degree of hazard, or the accident potential, in an industrial operation. The development of a procedure of this type would allow an industrial plant to determine the operations that have the greatest potential for causing an accident. Safety efforts would then be directed toward those operations of highest potential in an attempt to reduce accidents by focusing on those operations that have the greatest degree of inherent hazard. Once management has attempted to control the hazards within the operation, a re-evaluation of the operation can be made. In this way, management will have a current record of priorities for safety efforts.

Edward F. M. Hodge (11) has developed a hazard rating form that provides an objective, quantitative procedure for the evaluation of the degree of hazard in industrial operations. The objective of this thesis is to test the reliability and the predictive ability of the form. The use of this form should provide a means for determining those operations that cause the greatest number of accidents and the most severe accidents. Various industrial operations will be observed and the degree of hazard present will be quantitatively determined through the use of this form. These ratings will be correlated with historical accident data to determine the predictive ability of the procedure. The correlation developed will then be studied to determine the validity of the procedure.

CHAPTER II

DEVELOPMENT OF THE HAZARD POTENTIAL RATING FORM

As discussed in the preceding chapter, there are several accident-control procedures presently available to the safety engineer to be used in controlling accidents. Most of these procedures are concerned with either past accident performance, which results in the safety engineer spending more time in analyzing accidents that have already occurred than in trying to prevent future cases from occurring, or with the observation and evaluation of worker behavior, which emphasizes the unsafe acts of the workers rather than the hazards of the operation. There are very few procedures concerned with hazards that are inherent in industrial operations and the procedures that do exist depend primarily on subjective evaluations. However, a study conducted by a National Safety Council Committee yielded the following results (12):

18 percent of injuries due wholly to mechanical causes

19 percent of injuries due wholly to personal causes

63 percent due to a combination of both of these causes

Accidents are for the most part a combination of worker behavior and physical hazards. There are presently several accident-control procedures available that focus on worker behavior. What is now needed is a before-the-fact objective procedure that will allow the operation to be rated according to the degree of hazard present rather than rating the worker performing the operation. This type of procedure is needed in order to allow management to selectively control the distribution of the effort for accident control. The most effective safety program is concerned with directing its efforts toward those operations of greatest accident potential rather than with the elimination of all risks or hazards. This allows a favorable balance to be obtained between the cost of accident control and the reduction of accident cost. Management can direct its safety efforts toward those operations that receive the highest ratings and attempt to minimize the hazards that are inherent in the operation and that could lead to serious injury.

Edward F. M. Hodge (13) has developed a hazard potential rating form that will allow industrial operations to be evaluated according to the degree of hazard present. The remainder of this chapter will discuss the development of this form and the two following chapters will be concerned with the application and testing of the form.

The form developed is comparable in design to the job evaluation point rating form used by many companies. The completed form is a collection of relevant hazards. Similar to a job evaluation form, each hazard has been assigned a weight and the appropriate number of degrees has been determined and the degrees have been defined.

The initial step in the development of the Hazard Potential Rating Form was to determine what hazards should be included in the form. Nine major elements of hazard were selected as it was felt that these elements were common to most industrial enterprises and data from the National Safety Council seemed to substantiate this decision. Once these elements were selected they were strictly defined (Table 1) in order to avoid repetition and overlap.

The next step was the accumulation of relevant data needed to develop the form. The data that were collected were analyzed to determine the importance of each type of hazard with reference to its cost to the company and the percentage contribution of each hazard element to the overall accident level. These two indicators of accident importance were balanced with each other and used in assigning weights to the individual hazard that was being considered.

The final step in the development of the form was the differentiation of each hazard into appropriate degrees, following the same procedure as used in establishing a job evaluation point rating system. It was arbitrarily decided that a scale consisting of five degrees was desired for the evaluation. These degrees of hazard were then clearly defined and points were assigned for each degree (Table 2). The column entitled "max pts." refers to the maximum number of rating points that can be assigned to that degree of hazard by the rating individual. In assigning points to each degree, a basic scale consisting of the numbers zero through four was used. The numbers of the basic scale were multiplied by the already determined weighting factor for each hazard element to arrive at the number of points assigned to each degree.

Following the definition of each degree and the assigning of points to each degree all of the hazard elements were then arranged into the completed Hazard Potential Rating Form (Table 3). The evaluation form also includes a section that allows the operation being rated to be adequately and sufficiently identified and also permits the inclusion of other relevant information.

The form developed was not intended to be representative of any particular industry. Rather it was developed to illustrate the procedure for developing a form of this type and was based on accident data taken from the industrial safety records accumulated and published by the National Safety Council (14). It was recommended that a separate form be developed for each company in order that the necessary hazards be included and that data relevant to the particular company be used. However, the development of this form was based on comprehensive accident data relevant to the total accident picture and the hazards included in the form represent practically all of the relevant hazards that cause accidents. Therefore, this form has a more universal aspect than was originally thought and the completed form shown in Table 3 will be the one subjected to the testing rather than developing a new form for each company investigated.

In the following chapters, specific industrial operations will be rated using the developed Hazard Potential Rating Form. The ratings arrived at will then be compared with past accident data to determine the effectiveness of the use of the Hazard Potential Rating Form as a measurement of hazard.

Table 1. Hazard Definitions

Manual Movement of Materials - Any movement of materials performed by the operator during the normal course of the job without mechanical aids will be considered as manual movement of materials. The movement shall be performed by the operator without the use of any mechanically operated handling equipment. The hazard must be presented directly by the material being moved and the consequences of making the move with the material. This excludes any hazard that might be present had the same action been performed without any material movement.

Mechanical Movement of Materials - Any movement of materials performed by the operator during the normal course of the job using mechanical aids will be considered as mechanical movement of materials. The movement shall be performed by the operator using mechanically operated handling equipment. The hazard must be presented directly by the material being moved and the consequences of making the move with the material. This excludes any hazard that might be present had the same action been performed without any material movement.

Falls on Same Level - Any fall generated by gravity following the loss of equilibrium and ability to maintain an upright position that results in the point of contact of the person falling being at the same level or above the surface supporting the person at the inception of the fall will be considered a fall on the same level. The fall is the result of the operator moving from one place to another and excludes any hazards that might be present unless the operator is required to move in the area of the hazard that could cause a fall.

Struck by Falling, Moving Object - Any object that receives its momentum

Table 1 continued

from being dropped or from falling from a height will be considered as a falling, moving object. The hazard is presented by the falling object and is due to the force with which the operator would be struck by the falling object. This excludes objects that are thrown either by machinery or by a person and is not concerned with the object once it has completed its fall.

Danger From Moving Machinery - Any operation performed by the operator during the normal course of the job during which the operator is exposed to moving machine parts will be considered as danger from moving machinery. The hazard is presented by moving teeth, splines, gears, projections, etc., which would be capable of striking the operator or catching the operator or his clothing. Also included is the hazard presented at the point-of-operation when the machinery is in use. This excludes any parts of the machinery that are not moving.

Bumping Into Objects - Any movement of the operator during the normal course of the job in which the operator supplies the impact when colliding with non-moving projections or obstructions will be considered as bumping into objects. The hazard is presented by the impact with the object and is due to the movement of the operator and is not due to the movement of the projection or obstruction. This excludes any projections or obstructions that could cause a fall.

Use of Hand Tools - Any use of mechanically or manually operated portable hand tools will be considered as the use of hand tools. The hazard is presented by the operation of the hand tool and not with the operation performed with the hand tool. If any type of hand tool is used during

Table 1 continued

any phase of the operation, the hazard presented must be considered in this category.

Danger from Electricity, Heat or Explosive - Any exposure to electricity, heat, or explosive material during the normal course of the job will be considered as danger from electricity, heat, or explosive. The hazard is presented by the inherent properties of the electricity, heat, and explosive material and is due to exposure to them.

Danger from Harmful Substances - Any exposure to radiation, caustics, toxic and noxious substances during the normal course of the job will be considered as danger from harmful substances. The hazard is presented by the inherent properties of these substances and is due to exposure to these substances.

Danger from Elevators, Hoists, and Conveyors - Any use of elevators, hoists, and conveyors during the normal course of the job will be considered to be danger from elevators, hoists, and conveyors. The hazard is directly due to the elevator, hoist, or conveyor and excludes the hazards presented by the movement of materials on the elevator, hoist, or conveyor.

Table 2. Degree Definitions and Degree Points

	Max. Pts.
I. Handling Objects	
1. Manual	
a. Minimum of manual handling required of operation.	0
b. Infrequent handling outside line of normal duty.	5
c. Intermittent handling operations necessary to work progress.	10
d. Frequent manual movement of heavy or bulky loads.	15
e. Continuous movement of heavy or bulky material.	20
2. Mechanical	
a. Little contact with mechanical handling equipment.	0
b. Infrequent need of mechanical handling equipment.	5
c. Operates in area where mechanical equipment operates frequently.	10
d. Uses mechanical equipment frequently in course of operation.	15
e. Continuous use of mechanical equipment.	20
II. Falls	
1. Same Level	
a. Operates in open area with few obstructions and non-slip flooring.	0
b. Operates in well organized area with normal flooring material.	2

(From "The Evaluation of Industrial Hazards Through Techniques of Job Evaluation," Unpublished M. S. Thesis by Edward F. M. Hodge, Georgia Institute of Technology, 1969.)

Table 2 continued	Max. Pts.
c. Works in cluttered area with clear aisles and normal flooring material.	4
d. Cluttered working area with frequent movements required.	6
e. Cluttered working area with frequent movements and slippery floor materials.	8
2. Different Level	
a. Operates at ground level at all times.	0
b. Infrequent need to ascend to elevated position.	3
c. Operates at elevated level with adequate safe-guards and infrequent moves.	6
d. Frequent movement at elevated level with adequate safeguards.	9
e. Operates frequently at elevated levels with few safeguards.	12
III. Struck by Falling Moving Object	
a. Works in area where there is little danger from above.	0
b. Works in area where small, light objects might fall at infrequent intervals.	4
c. Small or medium size objects tend to fall at infrequent intervals.	8
d. Small or medium objects fall at regular intervals.	12
e. Large or heavy objects have possibility of falling at frequent intervals.	16

Table 2 continued

		Max. Pts.
IV.	Danger from Moving Machinery	
	a. Operates in area containing no moving machine parts.	0
	b. Infrequent visits necessary to an area containing moving machine parts.	3
	c. Continuous indirect contact with moving machine parts.	6
	d. Direct contact incurred with moving machine parts.	9
	e. Operates machinery with exposed moving parts.	12
V.	Bumping into Objects	
	a. Works in open area with no obstructions.	0
	b. Works in well organized area.	2
	c. Cluttered area with clear operating area.	4
	d. Cluttered operating area with few movements required.	6
	e. Cluttered working area with frequent movement required.	8
VI.	Use of Hand Tools	
	a. Operation requires minimum contact with any hand tool.	0
	b. Operation requires use of simple hand tools at infrequent intervals.	1
	c. Operates simple hand tool as normal function of work.	2
	d. Operates complex hand tools at infrequent intervals.	3

Table 2 continued	Max. Pts.
e. Operates complex hand tool(s) as normal part of job.	
VII. Danger from Electricity, Heat, or Explosive	
a. Operates in clear area with minimum of exposure.	0
b. Operates in area where small amount of exposure is present.	3
c. Operation requires frequent visits to high danger areas.	6
d. Operates continuously in area where danger is present.	9
e. Works in area where electrical wire is exposed or dangerous materials are being moved about.	12
VIII. Danger from Harmful Substances	
a. Operates in open area with little chance of exposure.	0
b. Operates where small amount of exposure is possible.	2
c. Operation requires visits to high danger areas.	4
d. Operates in area where there is a high possibility of exposure.	6
e. Operates in high danger area with inadequate safeguards.	8
IX. Danger from Elevators, Hoists, or Conveyors	
a. Minimal contact with each.	0
b. Contact at infrequent intervals with guarded	

Table 2 continued	Max. Pts.
machinery.	1
c. Frequent contact with adequately guarded machinery.	2
d. Infrequent contact with unguarded moving parts.	3
e. Frequent contact with moving parts of unguarded machinery.	4

Table 3. Completed Hazard Potential Rating Form

Hazard	First Degree	Max. Pts.	Second Degree	Max. Pts.	Third Degree	Max. Pts.	Fourth Degree	Max. Pts.	Fifth Degree	Max. Pts.	Rating Points
Handling Objects											
Manual		0		5		10		15		20	
Mechanical		0		5		10		15		20	
Falls											
Same Level		0		2		4		6		8	
Diff. Level		0		3		6		9		12	
Fall., Mov. Obj.		0		4		8		12		16	
Machinery		0		3		6		9		12	
Bumping into Objs.		0		2		4		6		8	
Hand Tools		0		1		2		3		4	
Elec., Heat, Expl.		0		3		6		9		12	
Harmful Substances		0		2		4		6		8	
Elev., Hoists, Con.		0		1		2		3		4	

Total Hazard Rating ______________

Operation ______________________ Rater ______________

Department ______________________ Date ______________

Supervisor ______________________ Approved ______________

Remarks ____

____

(From "The Evaluation of Industrial Hazards Through Techniques of Job Evaluation," Unpublished M. S. Thesis by Edward F. M. Hodge, Georgia Institute of Technology, 1969.)

CHAPTER III

APPLICATION OF THE HAZARD POTENTIAL RATING FORM

The Hazard Potential Rating Form is used in the same manner as is the job evaluation point rating sheet. The jobs being rated are examined, hazard by hazard, and the appropriate number of points are assigned to each hazard according to its degree of accident potential. The points assigned to the individual hazard elements are then totaled to arrive at the total hazard rating for the operation. The rater should spend sufficient time studying each operation being rated so that no hazard present in the operation is overlooked. If necessary, the rater should consult with the worker performing the operation or with the supervisor of the operation in order that an accurate and complete evaluation of the hazard potential of the operation is obtained. Once the operation has been rated, a safety supervisor familiar with the operation should review and approve the completed rating form. Following the initial rating of an operation, the operation should be reviewed periodically to determine if any new hazards have been introduced that would require the operation to be re-evaluated. The operation should also be re-evaluated following any corrective action taken to reduce the degree of hazard in the operation.

The use of this procedure provides a means for obtaining a quantitative, objective rating of the degree of hazard present in an industrial operation. Although a certain degree of subjectiveness is inherent in any evaluation procedure, the use of the Hazard Potential Rating

Form will reduce the degree of subjectiveness through the use of precise, objective definitions of the hazard elements and the degree of hazard. These precise definitions require little interpretation by the rater and this serves to control the degree of subjectiveness of the procedure. The use of the procedure also insures that the operations will be compared on an equal basis. The Hazard Potential Rating Form contains the hazards to be considered and it is on this basis that job-to-job comparisons are made.

The Hazard Potential Rating Form was used to rate the operations in the Recapping Department at Gordy Tire Company in Atlanta, Georgia, and receiving dock operations at Smith Transfer Corporation in Atlanta, Georgia. The Recapping Department is responsible for reconditioning passenger and truck tires that have tire tread worn to a point where the tire is no longer safe to use but still has a useable tire carcass on which a new tread can be placed. This is done by cementing a piece of prepared rubber on the tire carcass and then vulcanizing the tire by subjecting it to heat and pressure in a mold. The receiving dock operations consist of loading and unloading trucks and repairing and maintaining the trucks. The operations conducted by the Recapping Department and the receiving dock operations present a variety of hazards that would usually be present in a typical industrial plant. The investigation of these operations through the use of the Hazard Potential Rating Form should provide a suitable test for determining the reliability and predictive ability of the form.

The historical accident data necessary for computing the reliability and predictive ability of the form were supplied in the form of

Workmen's Compensation Cases. These "medical cases" are accidents that resulted in injuries that made it necessary for the injured person to receive treatment by some outside medical source. This accident data includes the number of days of lost time in the cases of lost time accidents and also the actual cost of the medical treatment and disability payments under Workmen's Compensation Acts. The severity of each accident will be based on days of lost time and the cost of each accident will be based on only direct medical costs. The data supplied were analyzed to determine the number of accidents per operation, the average cost of an accident for each operation, and the severity (man-days lost) of the accidents that had occurred for each operation.

The testing of the Hazard Potential Rating Form will be discussed in the following chapter. The Hazard Potential Rating Form was applied to specific operations to determine an objective, quantitative rating for the degree of hazard within these operations. These ratings should indicate the most hazardous operations or the operations with the greatest potential for causing an accident. Using the historical data that was supplied, correlation coefficients will be developed for this data and the ratings that were computed in order to determine the degree of predictive ability of the form. The reliability of the procedure will also be investigated.

CHAPTER IV

TESTING OF THE HAZARD POTENTIAL RATING FORM

The Hazard Potential Rating Form was tested in the Recapping Department of the Gordy Tire Company in Atlanta, Georgia, and on receiving dock operations at Smith Transfer Corporation in Atlanta, Georgia. The following operations were rated at Gordy Tire Company using the Hazard Potential Rating Form:

Receiving and Inspection - This operation consists of first unloading tires that are delivered to be recapped. After the tires are unloaded they are placed on a machine that spreads the tire and rotates it to allow the tire to be easily and thoroughly inspected. Occasionally it is also necessary to unload three hundred pound boxes of prepared rubber.

Buffing - This operation consists of buffing off the tread on the tires that are to be recapped. The tires are placed in a machine with a rotating buffing wheel and are subjected to the buffing wheel until the desired amount of rubber has been removed. Occasionally this operation is done with a portable hand buffer.

Cementing - In this operation cement is applied to the tire to cover any worn places left in the tire after the tread has been buffed off. The cement is highly flammable and there is also a danger of an explosion occurring.

Build-Up - This operation consists of winding strips of prepared rubber around the tire carcass to form a basis for applying the new tread. The tire carcasses are inserted in machines that rotate the tire carcasses while applying the strips of prepared rubber.

Bagging and Rimming - In this operation the curing bag and rim are inserted in the tire. The tire is placed on a machine that spreads the tire and allows the bag and rim to be easily inserted.

Molding - In this operation the tread is forced on the tires and the tires are vulcanized. The tires are placed in molds and the molds are heated to 300°F. The molds are then inserted in a machine and are subjected to pressure. Following this, the tires are removed from the machine and the mold.

Trimming and Clean-Up - This operation consists of removing any excess rubber from the tire and then removing any blemishes that are on the tire.

The management of the Gordy Tire Company cooperated fully in the investigation of these operations. The author was allowed unrestricted freedom in observing the operations and consultation with all supervisors and workers was permitted.

The following operations were rated at Smith Transfer Corporation using the Hazard Potential Rating Form:

Receiving and Shipping - This operation consists of loading outgoing trucks and unloading incoming trucks. The loads consist of a variety of commodities and both manual and mechanical methods are used in handling the loads.

Driver - In this operation only the loading and unloading performed by the drivers of trucks making deliveries within the city will be considered.

<u>Maintenance</u> - This operation consists primarily of fueling trucks, cleaning trailers, and checking tires, lights, etc. to insure that the truck is roadworthy. Occasionally it is necessary to assist the mechanic with his duties.

<u>Mechanic</u> - This operation consists of the maintenance and repair of the mechanical parts of the trucks.

In determining ratings for these operations the author was greatly aided by the dispatcher at Smith Transfer Company, who was thoroughly familiar with the operations rated.

The operations described above were observed and were rated using the Hazard Potential Rating Form. The ratings determined for each operation represent an objective evaluation of the degree of hazard within the industrial operation. The operations receiving the highest ratings are the operations with the greatest degree of inherent hazard and are those operations that, discounting human behavior, should cause the greatest number of accidents and the most severe accidents. The ability of the rating form to predict the operations that cause the most accidents and the most severe accidents will be tested through correlation of the ratings determined and past accident data of the operations rated. The past accident data supplied included accident records for 1967 and 1968 for Gordy Tire Company and records for the last quarter of 1967, entire year of 1968, and the first quarter of 1969 for Smith Transfer Corporation. This was the only accident data that was available. The rating for each operation and the historical accident data pertaining to each operation are listed in Table 4 (Gordy Tire Company) and Table 5 (Smith Transfer Corporation).

In developing correlation coefficients for the ratings and the historical accident data, a linear correlation was assumed due to the small sample size. The following formula from E. S. Buffa (15) was used in computing the correlation coefficients:

$$r = \frac{N\sum_{i=1}^{N} X_i Y_i - (\sum_{i=1}^{N} X_i)(\sum_{i=1}^{N} Y_i)}{\sqrt{\left[N\sum_{i=1}^{N} X_i^2 - (\sum_{i=1}^{N} X_i)^2\right] \cdot \left[N\sum_{i=1}^{N} Y_i^2 - (\sum_{i=1}^{N} Y_i)^2\right]}}$$

Where: X_i = Hazard Potential Rating of the operation for $i = 1$ to N.

Y_i = (1) accidents per operation, (2) accidents per employee performing operation, (3) severity (mandays lost) per operation, (4) average cost per accident, for the operation for $i = 1$ to N.

N = number of operations rated.

Following the determination of the correlation coefficients, the coefficients were tested using a one-tailed test of Student's t distribution to determine at what level of significance the corresponding population correlation coefficient differs from zero.

Following are the correlation coefficients and the levels of significance computed for the operations at Gordy Tire Company. The coefficient of correlation between the ratings determined and the number of accidents per operation was computed and found to be 0.93. This would indicate that the number of accidents per operation was positively correlated with the hazard ratings. The coefficient was tested for significance and it was determined that the coefficient of correlation was significantly different from zero at a 0.5 per cent level of significance. However, the number of accidents per operation is dependent on the amount of exposure of the employees performing the operation. Thus, a correlation coefficient was computed for the hazard ratings and the accidents per employee performing the operation. This correlation coefficient was found to be equal to 0.81 and it was determined that the coefficient of correlation was significantly different from zero at a 2.5 per cent level of significance. This is an indication that the number of accidents per employee performing the operation is directly correlated with the hazard ratings. A coefficient of correlation was computed to determine the degree of correlation between the hazard ratings and the severity (mandays lost) of the accidents resulting from each operation. The correlation coefficient was computed to be 0.96 and it was found that this figure was significantly different from zero at a 0.05 per cent level of significance. This also indicates the relationship of a positive correlation between the hazard ratings and the severity of the accidents due to each operation. A correlation coefficient was also computed to determine the degree of correlation between the hazard ratings and the average cost per accident for an operation. This correlation coefficient was found to be 0.50 which indicates only a slight degree of correlation. However, it is felt that not enough accidents had occurred to present an accurate value for the average cost per accident for several of the operations.

Following are the correlation coefficients and the levels of significance computed for the operations at Smith Transfer Corporation.

The coefficient of correlation between the ratings determined and the number of accidents per operation was computed and found to be 0.98. This figure was tested for significance and found to be significantly different from zero at a 2.5 per cent level of significance. This would indicate a positive correlation between the hazard ratings and the number of accidents per operation. However, in order to compensate for the amount of exposure for becoming involved in an accident, a correlation coefficient was computed between the hazard ratings for the operations and the number of accidents per employee performing the operation. This correlation coefficient was found to be 0.61, which indicates a slight degree of correlation. However, in computing the number of accidents per driver performing the driving operation, the total number of drivers making city deliveries was used. Some of the drivers spend more time unloading and loading trucks than do other drivers. There was no way to compensate for this unequal exposure to hazards and it is reflected in the computed correlation coefficient. A direct correlation was shown between the hazard ratings and the average cost per accident for an operation. This correlation coefficient was computed and was found to be 0.84 and it was determined that the coefficient was significantly different from zero at a 10.0 per cent level of significance. A positive correlation was also indicated between the ratings for the operations and the severity (mandays lost) of the accidents for an operation. The correlation coefficient was computed to be 0.98 and it was found that the coefficient was significantly different from zero at a 2.5 per cent level of significance.

For one plant the analysis of the predictive ability of the

Hazard Potential Rating Form indicated that the hazard ratings determined were positively correlated with (1) the number of accidents per operation, (2) the number of accidents per employee performing the operation, and (3) the severity (mandays lost) of the accidents per operation. A slight correlation was indicated between the hazard ratings and the average cost per accident for an operation. For the other plant, the analysis indicated that the hazard ratings determined were positively correlated with (1) the number of accidents per operation, (2) the average cost per accident for an operation, and (3) the severity (mandays lost) of the accidents per operation. A slight correlation was indicated between the hazard ratings and the number of accidents per employee performing the operation. The correlation coefficients and the levels of significance computed are summarized in Table 6.

Table 4. Comparison of Hazard Ratings and Historical Accident Data (Gordy Tire Company)

Operation	Rating	Number of Accidents	Avg Cost per Accident	Severity (Mandays Lost)
Molding	28	7	$43.00	14
Receiving and Inspection	20	3	32.00	10
Bagging and Rimming	19	5	28.00	7
Cementing	15	3	50.00	0
Trimming and Clean-Up	12	1	44.00	0
Buffing	12	0	-	-
Build-Up	10	0	-	-

Accident data based on medical cases from 1967 and 1968.

Table 5. Comparison of Hazard Ratings and Historical Accident Data (Smith Transfer Corporation)

Operation	Rating	Number of Accidents	Avg Cost per Accident	Severity (Mandays Lost)
Receiving and Shipping	35	7	$94.60	32
Driver	29	7	22.10	18
Maintenance	14	1	15.00	3
Mechanic	11	0	-	-

Accident data based on medical cases from the last quarter of 1967, entire year of 1968, and first quarter of 1969.

Table 6. Computed Correlation Coefficients and Levels of Significance

Gordy Tire Company		
	Correlation Coefficient	Level of Significance
Number of Accidents per Operation	.93	0.5%
Number of Accidents per Employee Performing Operation	.81	2.5%
Severity (Mandays Lost) of Accidents per Operation	.96	0.05%
Average Cost per Accident per Operation	.50	15.0%

Smith Transfer Corporation		
	Correlation Coefficient	Level of Significance
Number of Accidents per Operation	.98	2.5%
Number of Accidents per Employee Performing Operation	.61	20.0%
Severity (Mandays Lost) of Accidents per Operation	.98	2.5%
Average Cost per Accident per Operation	.84	10.0%

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The objective of this thesis was to test the predictive ability of a previously developed form, similar to a job evaluation point rating form, that had been designed to evaluate the degree of hazard in industrial operations. It was thought that the use of this form would permit the operations causing the most accidents and the most severe accidents to be determined in advance so that preventive measures could be selectively applied. These operations should correspond to the operations receiving the highest ratings.

Seven operations in the Recapping Department at Gordy Tire Company and four receiving dock operations at Smith Transfer Corporation were observed and rated. The hazard ratings determined were then tested by linear correlation with historical accident data for the operations rated. For the operations observed at Gordy Tire Company, this analysis indicated a positive correlation existed between the hazard ratings and (1) the number of accidents per operation at a 0.5 per cent level of significance, (2) the number of accidents per employee performing the operation at a 2.5 per cent level of significance, and (3) the severity (mandays lost) of the accidents per operation at a 0.05 per cent level of significance. A very slight correlation was indicated between the hazard ratings and the average cost per accident for an operation. For the operations observed at Smith Transfer Corporation, this analysis indicated a positive correlation existed between the hazard ratings and

(1) the number of accidents per operation at a 2.5 per cent level of significance, (2) the average cost per accident for an operation at a 10.0 per cent level of significance, and (3) the severity (mandays lost) of the accidents per operation at a 2.5 per cent level of significance. A slight correlation was indicated between the hazards ratings and the number of accidents per employee performing the operation.

These results indicate that the use of the Hazard Potential Rating Form should provide an effective procedure to evaluate the degree of hazard in an industrial operation. However, it is recommended that the form be subjected to further testing in order to verify the results obtained in this thesis. Further investigation should also be done to determine if the assumption of a linear correlation was valid. It is also recommended that the use of the form be implemented into an actual operating safety program. The safety performance should then be observed to determine if there is any significant reduction of accidents.

APPENDIX

HAZARD POTENTIAL RATING FORMS FOR RATED OPERATIONS

The following pages contain completed Hazard Potential Rating Forms for the operations rated at Gordy Tire Company and Smith Transfer Corporation.

Hazard Potential Rating Form

Hazard	First Degree	Max. Pts.	Second Degree	Max. Pts.	Third Degree	Max. Pts.	Fourth Degree	Max. Pts.	Fifth Degree	Max. Pts.	Rating Points
Handling Objects											
Manual		0	5	5		10		15		20	5
Mechanical	0	0		5		10		15		20	0
Falls											
Same Level	0	0		2		4		6		8	0
Diff. Level	0	0		3		6		9		12	0
Fall., Mov. Obj.		0	4	4		8		12		16	4
Machinery		0		3		6	9	9		12	9
Bumping into Objs.	0	0		2		4		6		8	0
Hand Tools	0	0		1		2		3		4	0
Elec., Heat, Expl.		0		3		6	9	9		12	9
Harmful Substances	0	0		2		4		6		8	0
Elev., Hoists, Con.		0	1	1		2		3		4	1

Total Hazard Rating 28

Operation Molding

Rater Harris

Department Recap

Date 2/26/69

Supervisor

Approved

Remarks

Hazard Potential Rating Form

Hazard	First Degree	Max. Pts.	Second Degree	Max. Pts.	Third Degree	Max. Pts.	Fourth Degree	Max. Pts.	Fifth Degree	Max. Pts.	Rating Points
Handling Objects											
Manual		0		5	10	10		15		20	10
Mechanical	0	0		5		10		15		20	0
Falls											
Same Level		0		2	4	4		6		8	4
Diff. Level		0	3	3		6		9		12	3
Fall., Mov. Obj.	0	0		4		8		12		16	0
Machinery		0	3	3		6		9		12	3
Bumping into Objs.	0	0		2		4		6		8	0
Hand Tools	0	0		1		2		3		4	0
Elec., Heat, Expl.	0	0		3		6		9		12	0
Harmful Substances	0	0		2		4		6		8	0
Elev., Hoists, Con.	0	0		1		2		3		4	0

Total Hazard Rating 20

Operation Receiving and Inspection

Rater Harris

Department Recap

Date 2/26/69

Supervisor

Approved

Remarks

Hazard Potential Rating Form

Hazard	First Degree	Max. Pts.	Second Degree	Max. Pts.	Third Degree	Max. Pts.	Fourth Degree	Max. Pts.	Fifth Degree	Max. Pts.	Rating Points
Handling Objects											
Manual		0	5	5		10		15		20	5
Mechanical	0	0		5		10		15		20	0
Falls											
Same Level	0	0		2		4		6		8	0
Diff. Level	0	0		3		6		9		12	0
Fall., Mov. Obj.		0	4	4		8		12		16	4
Machinery		0		3		6	9	9		12	9
Bumping into Objs.	0	0		2		4		6		8	0
Hand Tools		0	1	1		2		3		4	1
Elec., Heat, Expl.	0	0		3		6		9		12	0
Harmful Substances	0	0		2		4		6		8	0
Elev., Hoists, Con.	0	0		1		2		3		4	0

Total Hazard Rating 19

Operation Bagging and Rimming

Rater Harris

Department Recap

Date 2/26/69

Supervisor ______

Approved ______

Remarks ______

Hazard Potential Rating Form

Hazard	First Degree	Max. Pts.	Second Degree	Max. Pts.	Third Degree	Max. Pts.	Fourth Degree	Max. Pts.	Fifth Degree	Max. Pts.	Rating Points
Handling Objects											
Manual		0	5	5		10		15		20	5
Mechanical	0	0		5		10		15		20	0
Falls											
Same Level	0	0		2		4		6		8	0
Diff. Level	0	0		3		6		9		12	0
Fall., Mov. Obj.	0	0		4		8		12		16	0
Machinery	0	0		3		6		9		12	0
Bumping into Objs.	0	0		2		4		6		8	0
Hand Tools	0	0		1		2		3		4	0
Elec., Heat, Expl.		0		3	6	6		9		12	6
Harmful Substances		0		2	4	4		6		8	4
Elev., Hoists, Con.	0	0		1		2		3		4	0

Total Hazard Rating 15

Operation Cementing

Rater Harris

Department Recap

Date 2/26/69

Supervisor ____

Approved ____

Remarks ____

Hazard Potential Rating Form

Hazard	First Degree	Max. Pts.	Second Degree	Max. Pts.	Third Degree	Max. Pts.	Fourth Degree	Max. Pts.	Fifth Degree	Max. Pts.	Rating Points
Handling Objects											
Manual	0	0		5		10		15		20	0
Mechanical	0	0		5		10		15		20	0
Falls											
Same Level		0		2	4	4		6		8	4
Diff. Level	0	0		3		6		9		12	0
Fall., Mov. Obj.	0	0		4		8		12		16	0
Machinery		0		3	6	6		9		12	6
Bumping into Objs.	0	0		2		4		6		8	0
Hand Tools		0		1	2	2		3		4	2
Elec., Heat, Expl.	0	0		3		6		9		12	0
Harmful Substances	0	0		2		4		6		8	0
Elev., Hoists, Con.	0	0		1		2		3		4	0

Total Hazard Rating 12

Operation Trimming and Clean-Up

Rater Harris

Department Recap

Date 2/26/69

Supervisor __________

Approved __________

Remarks __________

Hazard Potential Rating Form

Hazard	First Degree	Max. Pts.	Second Degree	Max. Pts.	Third Degree	Max. Pts.	Fourth Degree	Max. Pts.	Fifth Degree	Max. Pts.	Rating Points
Handling Objects											
Manual	0	0		5		10		15		20	0
Mechanical	0	0		5		10		15		20	0
Falls											
Same Level	0	0		2		4		6		8	0
Diff. Level	0	0		3		6		9		12	0
Fall., Mov. Obj.	0	0		4		8		12		16	0
Machinery		0		3		6	9	9		12	9
Bumping into Objs.	0	0		2		4		6		8	0
Hand Tools		0		1		2	3	3		4	3
Elec., Heat, Expl.	0	0		3		6		9		12	0
Harmful Substances	0	0		2		4		6		8	0
Elev., Hoists, Con.	0	0		1		2		3		4	0

Total Hazard Rating 12

Operation Buffing

Rater Harris

Department Recap

Date 2/26/69

Supervisor ______

Approved ______

Remarks ______

Hazard Potential Rating Form

Hazard	First Degree	Max. Pts.	Second Degree	Max. Pts.	Third Degree	Max. Pts.	Fourth Degree	Max. Pts.	Fifth Degree	Max. Pts.	Rating Points
Handling Objects											
Manual	0	0		5		10		15		20	0
Mechanical	0	0		5		10		15		20	0
Falls											
Same Level		0	2	2		4		6		8	2
Diff. Level	0	0		3		6		9		12	0
Fall., Mov. Obj.	0	0		4		8		12		16	0
Machinery		0		3	6	6		9		12	6
Bumping into Objs.		0	2	2		4		6		8	2
Hand Tools	0	0		1		2		3		4	0
Elec., Heat, Expl.	0	0		3		6		9		12	0
Harmful Substances	0	0		2		4		6		8	0
Elev., Hoists, Con.	0	0		1		2		3		4	0

Total Hazard Rating 10

Operation Build-Up

Rater Harris

Department Recap

Date 2/26/69

Supervisor ______

Approved ______

Remarks ______

<u>Hazard Potential Rating Form</u>

Hazard	First Degree	Max. Pts.	Second Degree	Max. Pts.	Third Degree	Max. Pts.	Fourth Degree	Max. Pts.	Fifth Degree	Max. Pts.	Rating Points
Handling Objects											
Manual		0		5		10	15	15		20	15
Mechanical		0	5	5		10		15		20	5
Falls											
Same Level		0		2	4	4		6		8	4
Diff. Level		0	3	3		6		9		12	3
Fall., Mov. Obj.	0	0		4		8		12		16	0
Machinery	0	0		3		6		9		12	0
Bumping into Objs.		0	2	2		4		6		8	2
Hand Tools		0		1	2	2		3		4	2
Elec., Heat, Expl.		0	3	3		6		9		12	3
Harmful Substances	0	0		2		4		6		8	0
Elev., Hoists, Con.		0	1	1		2		3		4	1

Total Hazard Rating 35

Operation Receiving and Shipping

Rater Harris

Department Dock

Date 2/10/69

Supervisor ____________________

Approved ____________________

Remarks ____________________

Hazard Potential Rating Form

Hazard	First Degree	Max. Pts.	Second Degree	Max. Pts.	Third Degree	Max. Pts.	Fourth Degree	Max. Pts.	Fifth Degree	Max. Pts.	Rating Points
Handling Objects											
Manual		0		5	10	10		15		20	10
Mechanical	0	0		5		10		15		20	0
Falls											
Same Level		0		2	4	4		6		8	4
Diff. Level		0		3	6	6		9		12	6
Fall., Mov. Obj.	0	0		4		8		12		16	0
Machinery	0	0		3		6		9		12	0
Bumping into Objs.		0		2	4	4		6		8	4
Hand Tools		0		1	2	2		3		4	2
Elec., Heat, Expl.		0	3	3		6		9		12	3
Harmful Substances	0	0		2		4		6		8	0
Elev., Hoists, Con.	0	0		1		2		3		4	0

Total Hazard Rating 29

Operation Driver

Rater Harris

Department Dock

Date 3/10/69

Supervisor

Approved

Remarks

Hazard Potential Rating Form

Hazard	First Degree	Max. Pts.	Second Degree	Max. Pts.	Third Degree	Max. Pts.	Fourth Degree	Max. Pts.	Fifth Degree	Max. Pts.	Rating Points
Handling Objects											
Manual	0	0		5		10		15		20	0
Mechanical	0	0		5		10		15		20	0
Falls											
Same Level		0	2	2		4		6		8	2
Diff. Level		0	3	3		6		9		12	3
Fall., Mov. Obj.	0	0		4		8		12		16	0
Machinery		0	3	3		6		9		12	3
Bumping into Objs.	0	0		2		4		6		8	0
Hand Tools		0		1	2	2		3		4	2
Elec., Heat, Expl.	0	0		3		6		9		12	0
Harmful Substances	0	0		2		4		6		8	0
Elev., Hoists, Con.		0	1	1		2		3		4	1

Total Hazard Rating 11

Operation Mechanic

Rater Harris

Department Dock

Date 3/10/69

Supervisor

Approved

Remarks

Hazard Potential Rating Form

Hazard	First Degree	Max. Pts.	Second Degree	Max. Pts.	Third Degree	Max. Pts.	Fourth Degree	Max. Pts.	Fifth Degree	Max. Pts.	Rating Points
Handling Objects											
Manual	0	0		5		10		15		20	0
Mechanical	0	0		5		10		15		20	0
Falls											
Same Level		0	2	2		4		6		8	2
Diff. Level		0	3	3		6		9		12	3
Fall., Mov. Obj.	0	0		4		8		12		16	0
Machinery		0	3	3		6		9		12	3
Bumping into Objs.	0	0		2		4		6		8	0
Hand Tools	0	0		1		2		3		4	0
Elec., Heat, Expl.		0		3	6	6		9		12	6
Harmful Substances	0	0		2		4		6		8	0
Elev., Hoists, Con.	0	0		1		2		3		4	0

Total Hazard Rating 14

Operation Maintenance

Rater Harris

Department Dock

Date 3/10/69

Supervisor

Approved

Remarks

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